Correlation of the Broadband Spectral Characteristics of Bottlenose Dolphin Signatures with Dolphin Behavior in the Mississippi Sound

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Abstract

A series of acoustic measurements and visual observations were made of Bottlenose dolphins in the Mississippi Sound. A portable acoustic monitoring system recorded dolphin echolocation clicks, wideband burst pulses and narrowband frequency modulated whistles. The signal spectra were correlated with observations of dolphin behavior. The results showed that when these dolphins are diving and traveling, the primary signals are short echolocation clicks. During what appeared to be social interactions, the signals were more complex broadband amplitude modulated whistles.

I. Introduction

Bottlenose dolphins (Tursiops truncatus) have three types of recognized acoustic vocalizations: (1) broadband clicks (2) wideband pulse bursts, and (3) narrowband whistles. The broadband clicks are used primarily for echolocation. The wideband pulse bursts and narrowband whistles are used to maintain contact with other group animals [1], cueing the direction of travel [2], and feeding [3, 4]. However, the function and meaning of these different signal types is still an area of investigation. An excellent discussion and series of references on the behavioral significance and the various functions of the dolphin communication processes are given in [5]. Acoustic signatures have also proven difficult to localize and correlate with free ranging dolphin behavior. Watkins and Schevill [6, 7], and Freitag and Tyack [8] demonstrated that signals from marine mammals can be localized, but made no attempt to correlate their behavior. There are no studies relating the broadband (3 to 200 kHz) spectral variabilities to dolphin behavior.

This paper reports on a part of a series of broadband acoustic measurements (3 to 200 kHz) taken from different groups of free ranging Atlantic Bottlenose dolphins that are regularly observed in the Mississippi Sound. The signature spectra were calculated and the variability compared to the observed surface behavior of several groups of dolphins. Dolphin group behavior was classified using the operational definitions used in Jones and Sayigh [9] and Ukian and Wells [10]. These are outlined in Table I

Table I

Diving: Simple diving and surfacing
Milling: Surfacing of dolphins in random directions
Travel: Surfacing of dolphins in one constant direction
Milling/Traveling: A combination traveling and surfacing
Feeding: Fish seen in mouths
Social interactions: Interactions among dolphins

II. Measurement Areas and Locations

A series of dolphin acoustic signature measurements were conducted over a 4-month period at a number of different locations in the Mississippi sound (Fig.1). The areas were around the Gulfport ship harbor, Ship Island, and Cat Island. In these areas the water depths ranged from 9 to 15 m.

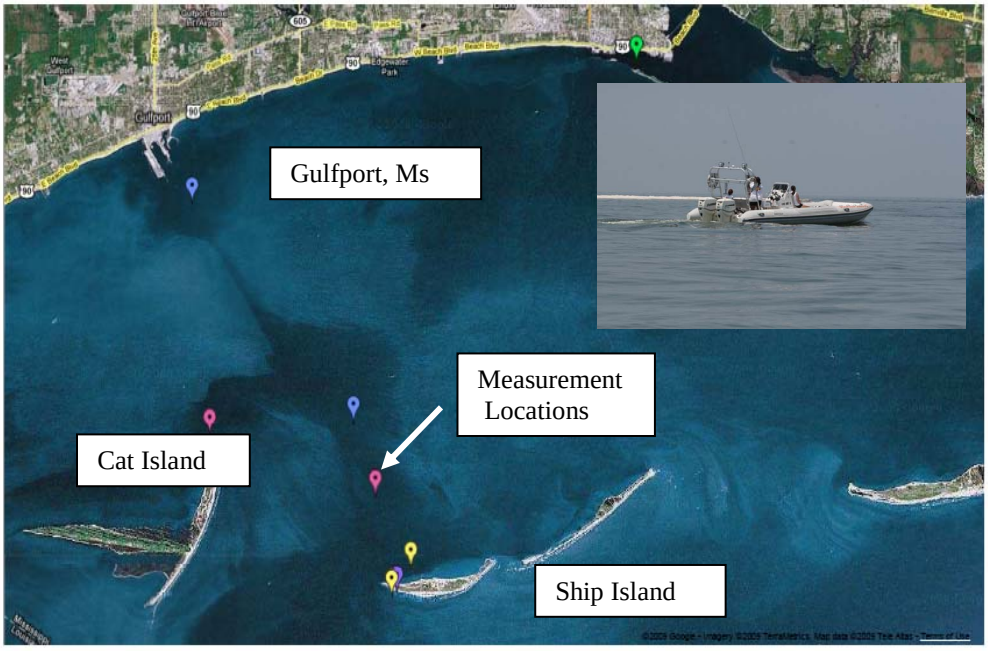


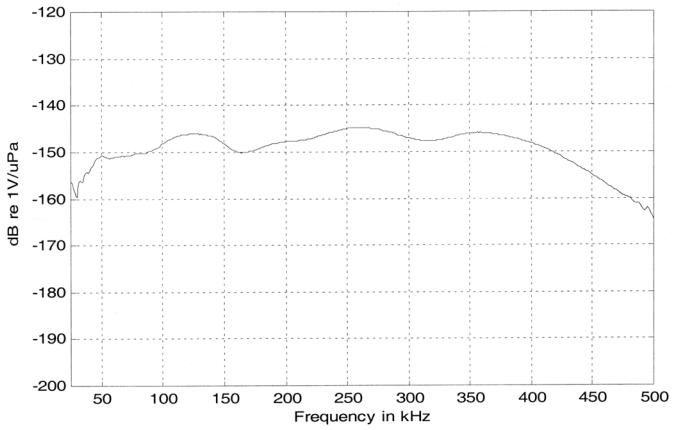
Fig 1. Measurement locations

As groups of dolphin were located, the engines of the small boat were turned off. A broadband hydrophone was lowered into the water to a depth 4.5 m and the dolphin signals recorded. At the same time, observers closely monitored dolphin surface activity, and categorized it according to Table I. These observations also included number of animals, adults/juveniles/calves, distribution within a group of animals, any notable activity (milling, traveling, socializing, sexual behavior, feeding, etc.).

III. Measurement System

The measurement system consisted of a single broadband hydrophone, a digitizing system and a laptop computer. The hydrophone response curve is shown in Fig.2. The dolphin signals were digitized at 500 kHz and stored on DVDs. In order to minimize electronic interference, the data acquisition system was powered by two 12 volt batteries.

(a)



(b)

Fig. 2. Data acquisition system (a), Hydrophone sensitivity curve (b)

IV. Results and Discussions

Fig. 3 shows a series of signals and broadband spectra for a group of about 40 dolphins that were diving near the north side of Cat Island. An example of a typical recorded time series is shown in Fig. 3a. Generally, signal lengths were on the order of 15 μsec and appeared to be

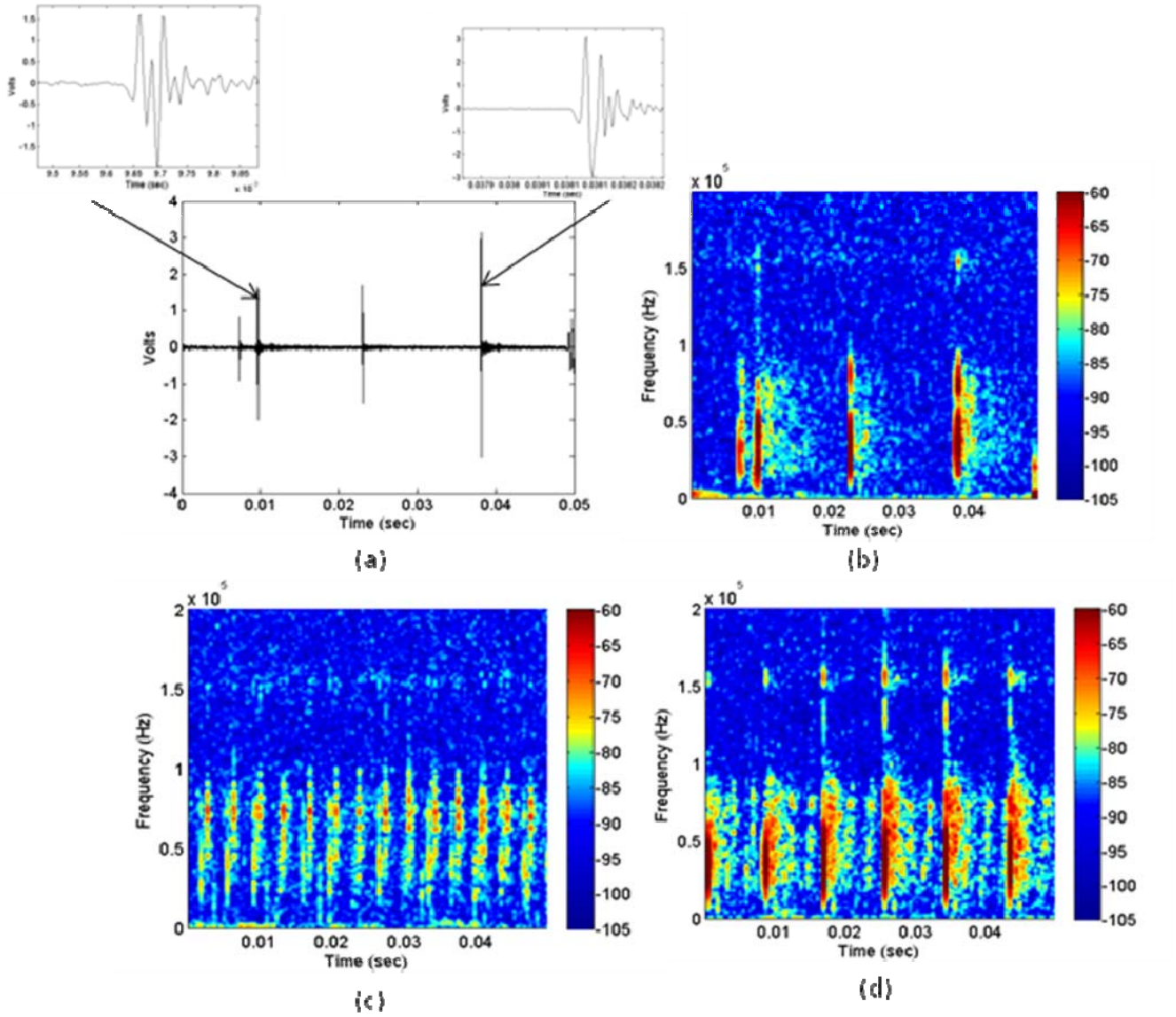


Fig. 3. Typical echolocation signals and spectra for dolphins that were observed diving and surfacing.

echolocation clicks. The spectra for this signal ranged from 3 to 95 kHz and is shown in Fig.3b. Fig.3c is an example of the signal spectra a few minutes later. These signatures have about the same bandwidth but with a higher repletion rate. The spectra shown in Fig.3d also shows similar frequency content except there was an increase in the high-frequency components (150 to 170 kHz). However, in all cases the most intense spectra was in the 3 to 95 kHz range. These signatures were typical for the times when the animals were observed diving and surfacing.

Another group of 30 dolphins with at least five calves was located near the north side of East Ship Island. These dolphins were, at times, diving and leaping out of the water. They also appeared to be engaged in general social interaction. The signals, recorded during these activities were different from those recorded when the animals were just diving. Fig.4 shows several examples of the recorded time series and signature spectra that correlated with these observations.

The signals shown in Fig.4a are similar to those shown in Fig.3a. While the echolocation signal lengths were similar, the signature spectra is considerably more broadband, and approached 200 kHz with the energy distributed over the entire spectrum (Fig.4b). Fig.4c is the echolocation spectra from the same animals, but at a later time. In this case the energy was not as evenly distributed across the spectrum.

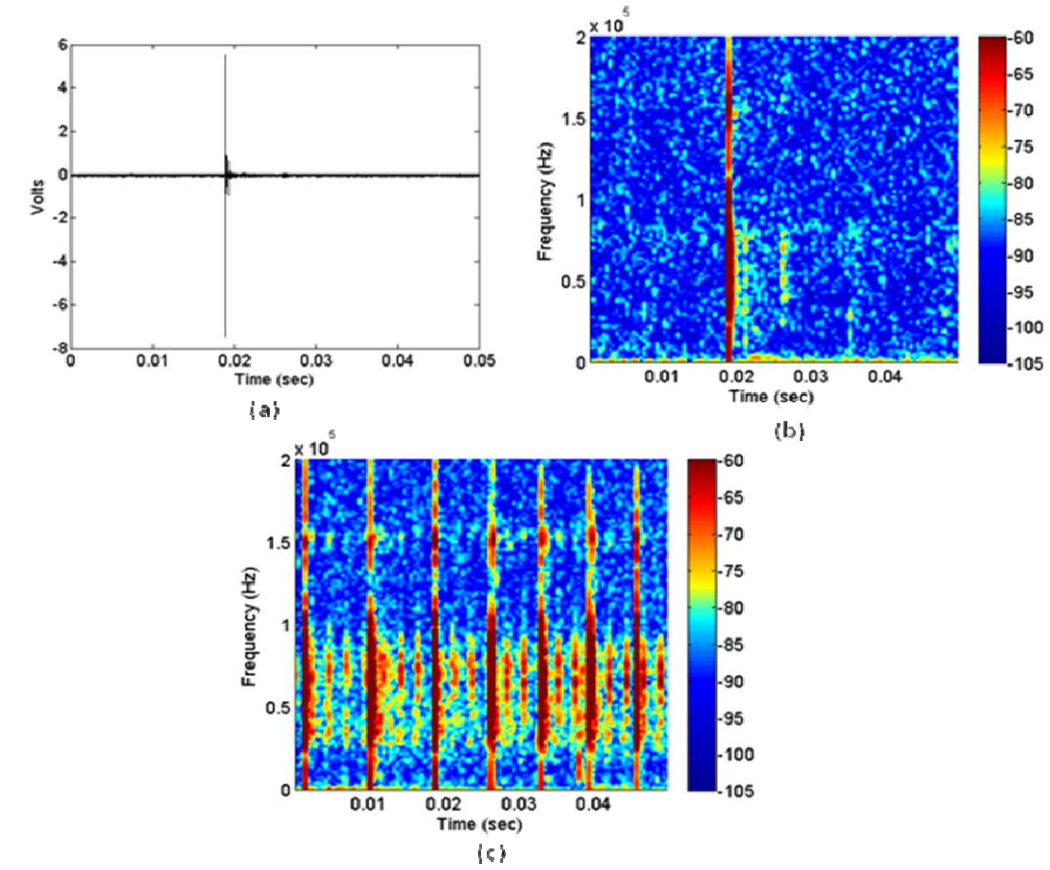


Fig. 4. Broadband echolocation signals and spectra for dolphins that were observed diving and surfacing.

At a later time, this group of animals were engaged in what appeared to be intense social interaction and aerial displays. Fig. 5 are examples of the recorded time series and spectra. Some of these signals are very different from those previously recorded. There were intense amplitude modulated pulsed signals that is an indicator of the type of social interaction that was occurring, but not easily observed. The signal's energy was distributed over the entire frequency spectrum, with longer signal spectra levels in the 190 to 200 kHz range.

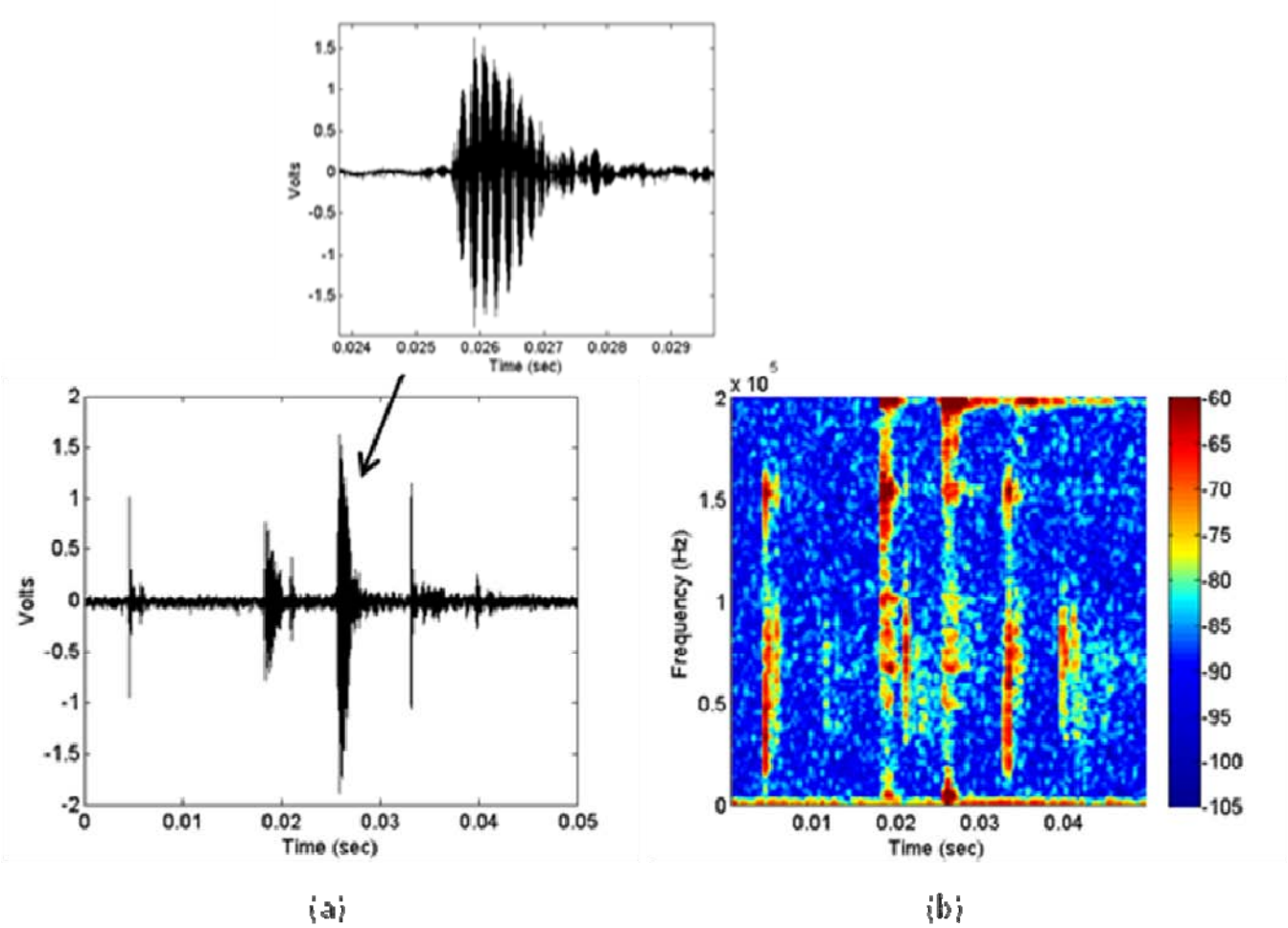


Fig. 5. Wideband amplitude modulated pulse bursts and spectra for the observed social interaction and aerial displays.

Fig. 6 are recorded echolocation clicks and spectra from the same group of animals as they began to again dive and surface. These signals closely resemble those in Figs.3a and 4a, except the energy in Fig. 6 extended over the entire bandwidth (3 to 200 kHz).

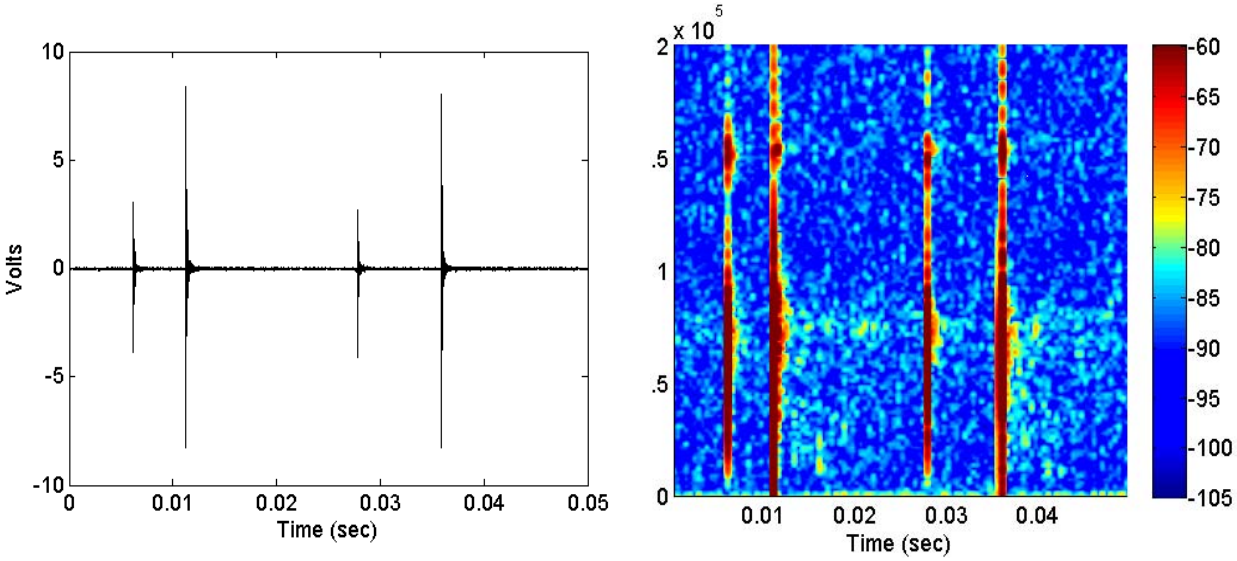
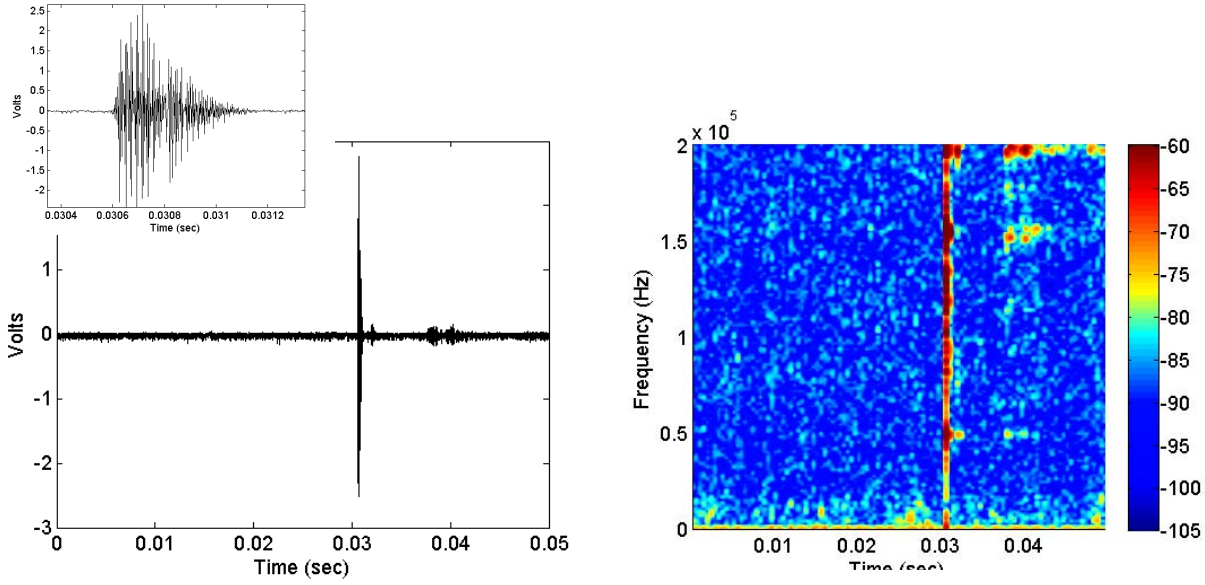


Fig. 6. Echolocation signals and spectra for dolphins observed diving and surfacing.

Figs. 7a and 7b were recorded from the same group of animals as they began to travel around the north side of East Ship Island. These signals were not typical of the echolocation signals

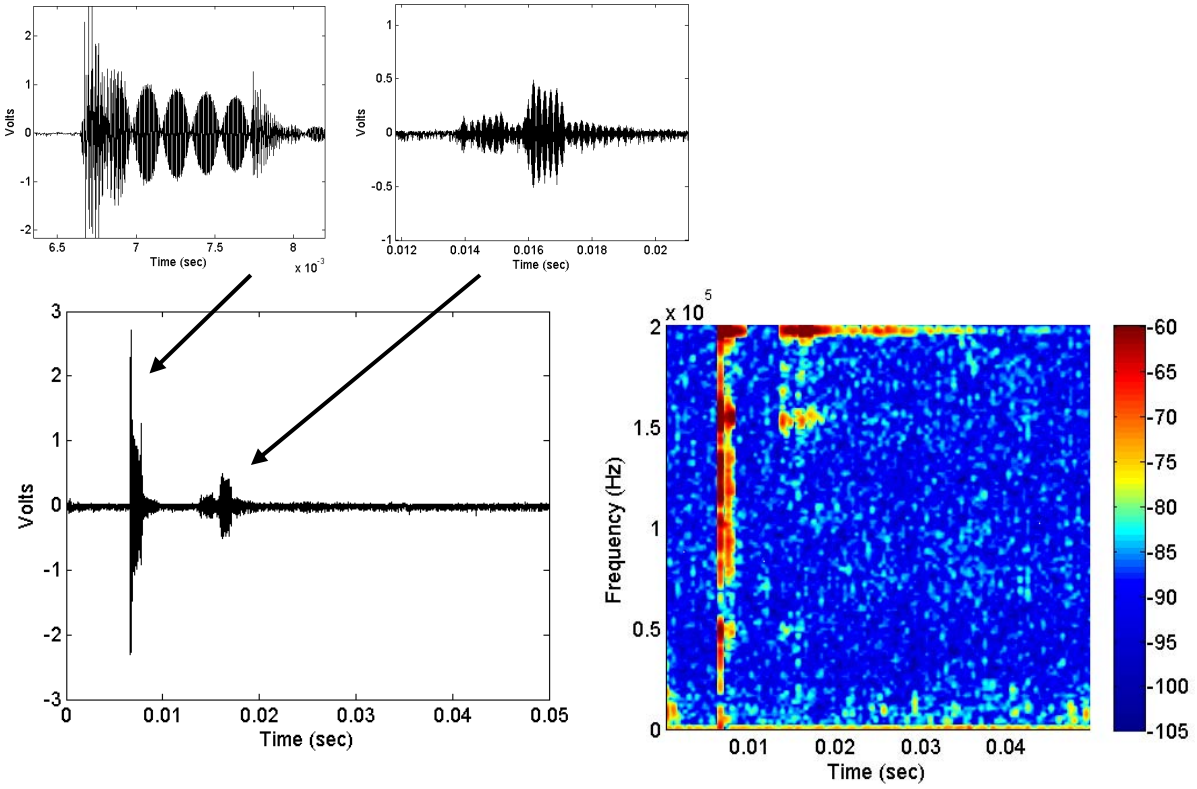


(a) (b)

Fig. 7. Echolocation signals and spectra for dolphins traveling near East Ship Island.

recorded at other times, and correlations with observed behavior were difficult. The duration of these signals is longer, (700 μsec) than the echolocation signal shown in Fig.3a. The increased length is possibly the result of boundary interactions. However, its spectra is also broadband, with the highest energy levels between 50 and 200 kHz.

As the dolphins began traveling, different signal types was recorded and an example is shown in Fig.8a. The first signal initially replicated that in Fig.7a, but is combined with an amplitude modulated signal. The end of the signal is also similar to that shown in Fig.7a. This signal is broadband, with most of the energy at the higher frequencies (Fig. 8b). The second signal is an amplitude modulated series of pulses. It is not clear what behavior is associated with these types of complex structure, but, it is believed to be an example of communication between the mature animals and their calves.



(a) (b)

Fig. 8. Broadband pulsed amplitude modulated signals

V. Summary

This paper reports on a series of broadband acoustic measurements that are correlated with the observed surface behavior of Atlantic Bottlenose dolphins in the Mississippi sound. The acoustic signals and spectra were time-correlated with visual observations of various dolphin behavior and social interaction. When the dolphins were diving and surfacing, the major signals were short broadband echolocation signals. Some were more broadband than others, with the signal energy distributed over the entire spectrum. However, some echolocation signals did have increased energy levels at the higher frequency. These echolocation clicks were typical of the signals that correlated with observations of dolphin diving and surfacing behavior.

Broadband pulse amplitude modulated signals were recorded when the dolphin groups appeared to be engaged in intense social interaction and aerial displays. This was especially true when calves are present. These signal types were complex with combinations of echolocation clicks and pulsed amplitude modulated signals. The spectra of these signals ranged from 3 to 200 kHz with longer duration signal energy in the 190 to 200 kHz frequency range.

The major limitation of these measurements was the inability to observe and describe the dolphin behavior, most of which typically takes place underwater. However, this study does provide further insight into the spectral variabilities that are associated with surface behavior and intense social interaction. This study also shows that dolphin signals can be extremely broadband, in many cases approaching 200 kHz.

VI. Acknowledgments

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VII. References

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